7.6-10447
CR-148524

SOIL, WATER, AND VEGETATION CONDITIONS IN SOUTH TEXAS

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July, 1976

TYPE II QUARTERLY PROGRESS REPORT
for Period April 13, 1976 to July 13, 1976

(E76-10447) SOIL, WATER, AND VEGETATION CONDITIONS IN SOUTH TEXAS Quarterly Progress Report, 13 Apr. - 13 Jul. 1976 (Agricultural Research Service) 17 p HC $3.50 CSCL 08F G3/43
N76-29677
Unclas
00447

Prepared for

GODDARD SPACE FLIGHT CENTER
Greenbelt, MD 20771

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SOIL, WATER, AND VEGETATION CONDITIONS IN SOUTH TEXAS		5. Report Date July 1976 6. Performing Organization Code
7. Author(s) Craig L. Wiegand, et al.		8. Performing Organization Report No.
9. Performing Organization Name and Address Agricultural Pesearch Service U. S. Department of Agriculture P. O. Box 267 Weslaco, Texas 78596		10. Work Unit No. 11. Contract or Grant No. S-53876-AG
12. Sponsoring Agency Name and Address GODDARD SPACE FLIGHT CENTER Greenbelt, MD 20771 Technical Monitor: G. R. Stonesifer, Code 902		13. Type of Report and Period Covered TYPE II Report 4/13/76 to 7/13/76 14. Sponsoring Agency Code QPR-6

15. Supplementary Notes

16. Abstract

Densitometric measurements made on an infrared color transparency of tree canopies with red-filtered light gave a statistically significant discrimination among three citrus varieties (Valencia and Marrs orange, and Redblush grapefruit) in agreement with their measured differences in leaf chlorophyll concentrations and field-measured reflectance spectra.

Measurements with a field spectroradiometer were made on 9 dates during the growing season over Milam and Penjamo wheat plantings. Reflectance data for the 0.9 μm wavelength and percent soil, vegetation, and shadow in the wheat scene on each measurement date are reported herein.

A method of normalizing soil background that is applicable to signature simplex, vegetation index, and composite canopy reflectance interpretations is introduced.

Results of photointerpretation and computer classifications of an 81,000 hectare rangeland area are presented.

Results of two methods of determining leaf area are compared.

17. Key Words (Selected by Author(s))	18. Distribution Statement
Orange; Grapefruit; Classification results; Wheat; Reflectance; Clouds; Land use; Range sites; Biomass; LAI; Plant population; Percent cover; Signature simplex	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
UNCLASSIFIED	UNCLASSIFIED		

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

TYPE II QUARTERLY PROGRESS REPORT

April 13, 1976 to July 13, 1976

A. Problems:

Two problems have been encountered this reporting period. One is an interruption in receipt of the LANDSAT STANDARD U.S. CATALOG. The last issue received was for the month of February 1976. Since we could not study the information in the catalog to determine scene quality and I.D. numbers, we have placed verbal orders with the ASCS Aerial photographic Laboratory based on their information. Using this procedure, we have ordered the usable images through June 8, 1976. Computer compatible tapes will be ordered from the EROS Data Center for selected scenes after examining the imagery.

The second problem is that the LANDSAT-2 MSS was turned off on May 2 before it reached our test site. This was unfortunate because it was the only completely cloudless satellite overpass day of the spring growing season. Then too, we had acquired excellent ground truth for both range and cropped (sorghum) fields for which there will be no corresponding LANDSAT MSS digital data for study.

It was mentioned in the last progress report that the accounts for data products at both the EROS Data Center and the ASCS Photographic Laboratory were approaching exhaustion. Supplemental accounts have been established at both locations to cover anticipated data needs for the remainder of the contract period.

B. Accomplishments:

Discrimination Among Citrus Varieties

A paper entitled "Reflectance and Photographic Characteristics of Three Citrus Varieties for Discrimination Purposes," has been prepared by H. W. Gausman, D. E. Escobar, and C. L. Wiegand. The Abstract follows:

Reflectance spectra were measured spectroradiometrically for single leaves in the laboratory and for tree canopies in the field, and aerial infrared color photos were taken for three citrus varieties [Valencia and Marrs oranges (*Citrus sinensis* (L.) Osbeck,) and Redblush grapefruit (*Citrus paradisi* Macf.)] to determine whether they were distinguishable based on their reflectance and photographic characteristics.

Redblush had the highest and Marrs had the lowest field-and laboratory-measured visible light (0.5 to 0.75 μm) reflectance; whereas, Redblush and Valencia had the highest and lowest near-infrared light (0.75 to 2.5 μm) reflectance. However, differences in reflectance among the varieties were larger for field measurements on intact trees than for laboratory measurements of single leaves over the entire 0.5- to 2.5-μm waveband.

Field measurements of visible light reflectance were directly related to the infrared color film's tonal characteristics; high reflectance (low chlorophyll concentration) gave a "pinkish" color and low reflectance (high chlorophyll concentration) gave a dark red color. Consequently, densitometric measurements made on an infrared color transparency of tree canopies with red-filtered light gave a statistically significant discrimination among the three varieties in agreement with their differences in chlorophyll concentrations.

Thus, discriminations were made among the three citrus varieties from both spectroradiometric and photographic characteristics of their foliage independently of soil background.

Seasonal Reflectance of Wheat

Two dissimilar varieties of wheat (*Triticum aestivum*, Milam and Penjamo) were planted in randomized plots on Hidalgo fine sandy loam soil to study their seasonal changes in reflectance. Milam is a winter wheat that is normally planted in south Texas as a fall and early spring grazing crop. Penjamo has a typical spring wheat growth habit and is normally used for a grain crop.

Reflectance data were taken with an Exotech Model 20 field spectroradiometer mounted on a boom of an aerial lift truck. The Model 20 spectroradiometer is a circular-variable-filter instrument that measures the amount of energy entering the instrument at all wavelengths from 0.45 to 2.50 μm as filters are rotated through the optical path in the instrument. Incident sun-and sky-light, and reflected light are measured as alternate 30-second scans. The optics direct the energy onto two sensors, a silica and a lead sulfide detector, which are responsive over the wavelength range of the instrument. Reflectance is calculated by comparing at each wavelength the amount of incident energy with the amount being reflected from the target area. Readings for this study were taken with 15 degree FOV optics looking straight down onto the wheat plots from 18 to 20 meters above ground level.

The wheats were seeded with a grain drill at rates of 50, 103, and 162 kg/ha in randomized plots each 30 meters square on November 20, 1976. The plots were arranged in two lines of four plots in each line so an aerial lift truck and mobile laboratory could be driven between the two rows of plots. By parking the truck at the corner of four plots, spectroradiometer readings could be taken from all four plots from a single setting of the truck. Thus, only two settings were required to reach all eight plots. Two variety-rate treatments were repeated so one treatment was represented in the set of plots measured at each setting of the truck.

Nine sets of measurements were taken from planting through maturity in mid April 1976. These nine sets represented the nine clear days during this time. Spectra were taken only between 1,000 and 1,500 hours LST to reduce the effect of sun angle on the reflectance. Three pairs of alternate incident and reflected spectra were scanned for each plot. All three

pairs of spectra were recorded on 7-channel analog magnetic tape with adequate housekeeping details to permit positive identification of the data in subsequent data processing procedure.

Data from the analog magnetic tapes were digitized through a high speed A/D converter and stored on bulk digital magnetic tape. Each set of digital data included the output of the two sensors, a wavelength indicator, the distinction between incident and reflected spectra, a code indicating the plot involved, and information on the gain settings of the signal amplifiers on the sensors.

A follow-up program read the data from the bulk digital tape, matched the incident and reflected spectra, calculated percent reflectance, and averaged the reflectance spectra from the individual plots. The averaged reflectance spectra were recorded on another digital tape for later summarization and comparison.

Photographs of each plot, centered on the instrument's FOV, were taken when spectroradiometer readings were taken. These photographs were studied in a density slicing image analyzing system. The area of soil, sunlit vegetation, and shade was measured in each photograph by the image analyzing system. These data are presented in Table 1.

Reflectance spectra were calculated from data collected December 9 and 31 in 1975, and on January 13, February 2, 11, 18, March 16, 17, and April 8 in 1976. The readings on February 11 and April 8 were limited to those plots closest to a field road because the plot area was too wet for the aerial lift truck to be driven between the plots.

All the curves obtained (Fig. 1) show the usual characteristic shape for vegetated surfaces. All show changes in reflectance related to date that are not necessarily associated with changes in plant cover or physiological stage of plant development. On February 11, the Penjamo had reached early boot stage; the Milam was still stooling. The reflectance curves do not separate by variety at this date. By March 16 and 17, there is a tendency for the curves to separate by variety, but at this time, the Penjamo could be considered mature; whereas, the still green Milam was beginning to boot. The maturing grain was consumed by birds, but the reflectance is not considered to be much different from normal wheat in spite of the bird damage.

All plots had reflectances similar to bare soil on December 9; at this early growth stage vegetative cover was less than 20 percent. At wavelengths 0.9 µm and longer, reflectance approached bare soil reflectance as the plants reached maturity and harvest stage. The deviations from the bare soil reflectance spectrum differed among wavelengths during the season, but they were greatest at all wavelengths during the period of vigorous vegetative growth and high chlorophyl concentration in the plant leaves (Fig. 1). Both varieties of wheat, and all seeding rates, followed similar spectral changes with time regardless of the physiological stage of plant development. Neither stooling, booting, nor heading were distinguishable from the spectra obtained at these growth stages.

Table 1. Percent of FOV of spectroradiometer in soil, sunlit vegetation, and shadow of three seeding rates of two varieties of wheat by date.

	VARIETY					
	Milam			Penjamo		
Seeding rate kg/ha	50	103	162	50	103	162
	%	%	%	%	%	%
			December 9, 1975			
Soil	66.8	75.4	75.6	81.6	78.4	80.0
Vegetation	19.1	14.6	15.7	11.5	13.7	13.5
Shadow	10.3	7.2	5.7	3.9	5.2	3.4
			December 31, 1975			
Soil	29.1	25.0	17.4	61.0	57.0	9.0
Vegetation	19.0	25.3	26.7	22.8	26.4	27.6
Shadow	48.7	46.2	52.4	12.9	12.3	60.1
			January 13, 1976			
Soil	12.1	8.1	2.2	17.6	8.2	0.0
Vegetation	45.6	46.6	54.4	29.3	34.8	48.4
Shadow	38.8	41.6	40.0	49.9	54.0	49.6
			February 2, 1976			
Soil	19.6	2.8	3.5	5.0	3.3	0.4
Vegetation	65.6	76.3	68.0	64.6	63.1	74.3
Shadow	11.4	19.2	26.3	28.0	31.1	23.8
			February 11, 1976			
Soil	0.0	0.0	0.0	0.4	1.1	-
Vegetation	76.1	76.3	79.2	78.2	77.1	-
Shadow	23.2	23.1	20.1	19.8	20.8	-
			March 16, 1976			
Soil	10.0	2.3	4.1	5.5	1.6	1.6
Vegetation	61.1	73.9	67.0	79.6	83.8	81.8
Shadow	26.2	21.5	27.1	10.4	13.3	14.4
			March 17, 1976			
Soil	8.8	10.2	0.0	0.0	0.0	0.0
Vegetation	52.8	52.0	60.0	64.8	62.6	63.3
Shadow	35.7	35.5	39.5	34.0	36.6	36.2

Rangeland Biomass

The major range sites in Kennedy and Willacy Counties have been botanically characterized and biomass measurements (Table 2) have been made for the spring (April 1976) period. The spring growing season usually begins here in mid February, but this year the winter and early spring were rainless. The rangeland did not "green up" until about April 1, following rainfall in late March.

As shown in Table 2, the two improved tight sandy loam sites were the most productive sites while the tight sandy loam-native, sandy mound-native, and the salty flat were the least productive. The herbaceaous biomass produced followed the same trend among range sites as shown in biomass measurements for the summer, fall, and winter periods (as reported in previous quarterly progress reports). The low biomass production sites are characterized by a dense woody plant canopy or high salinity.

We are continuing to take herbaceous biomass measurements on the coastal sand and deep sand-native sites each month throughout the growing season. We are separating these herbaceous measurements into four different components: (1) apical stem fractions and heads, (2) standing brown biomass, (3) standing green biomass (green leaves and green basal stem fractions), and (4) litter. These measurements will be continued through 1976 and the data will be presented in a later report.

Table 2. Herbaceous biomass production (air-dry weight) for various range sites in Kennedy and Willacy Counties, Texas, sampled in April 1976.

Range site	Forage production April 1976
	kg/hectare
Tight sandy loam-native	183
Tight sandy loam-improved, re-established native grasses and herbs	1,075
Tight sandy loam-improved, re-seeded with Aliciagrass	1,251
Coastal sand-native	711
Sandy mound-native	176
Deep sand-native	430
Deep sand-improved, re-established native grasses and herbs	728
Salty flat	252

Rangeland Classification

We have recently completed classification of an 81,000 hectare study area in Kennedy and Willacy Counties using both a photo interpretation estimate and a computer identification algorithm for the October 17, 1975 LANDSAT-2 overpass. Table 3 is a comparison of the photo interpretation hectarages and land area percentages for the various land use categories with the computer estimated areas and percentages. In four categories (mixed brush rangeland; lagunas; sand dunes, tidal flats, and salty flats; and water), the photo interpretation percentages were larger than the computer estimated percentages, while in three categories (grasslands; live oak rangeland; and idle cropland), the computer estimated percentages were larger than the photo interpretation percentages.

The photo interpretation and computer classification algorithms were both trained on test sites that had been identified by ground inspection to be characteristic of the named range sites. The photo interpretation was done by drawing boundaries on a 1:96,000 scale enlargement of the LANDSAT-2 image and determining the percentage of the area occupied by each land use category or range site. The computer classification was trained on the LANDSAT-2 spectral signatures for the same ground identified range sites that were used by the photo interpreter.

The largest difference in Table 3 is for the mixed brush rangeland category. This is a highly variable category because "mixed brush" ranges from 15 to 80% ground cover by woody vegetation. The range sites also grade from one to another so that boundary lines drawn by looking at images are highly subjective. The computer classification is based on discrete spectral classes, and a decision is made concerning each pixel representing approximately a 0.45-hectare area on the ground. A large proportion of the 7% of the area that fall into the threshold or unidentified category is composed of the boundary pixels between bare cropland and rangeland, canals, access roads, and US Highway 77 where the signatures are composites of natural and man-made features. Others are single or small groups of pixels within the rangeland itself that are spectrally different from the typical range sites for the category. Since the photointerpretation method ignored man-made features and did not treat the small areas that the digital data did, the computer classification can be considered the more precise.

Table 3. Comparison of photo interpretation percentages for the various land use categories with computer estimated percentages (using LANDSAT-2 MSS digital data of Kennedy and Willacy Counties study area) surveyed on October 17, 1975 (MSS bands 5, 6, and 7).

Land use categories	Photo interpretation		Computer	
	Size in hectares	Percent of study area	Size in hectares	Percent of study area
Grasslands (improved grasslands, re-established to introduced grasses, or native grasses and herbs)	2,916	3.6	5,508	6.8
Mixed brush rangeland (deep sand-native, coastal sand-native, and tight sandy loam-native range sites)	43,416	53.6	33,372	41.2
Live oak rangeland (sandy mound range site-native)	12,150	15.0	15,066	18.6
Lagunas (depressions)	3,159	3.9	2,268	2.8
Idle cropland (bare soil)	11,259	12.9	12,636	15.6
Sand dunes, tidal flats, and salty flats (predominantly bare soil)	4,374	5.4	3,321	4.1
Water	3,726	4.6	3,159	3.9
Threshold	-	-	5,670	7.0
Total	81,000	100.0	81,000	100.0

Normalization of Soil Background Reflectance

A paper entitled, "A Bare Soil Background Normalization for Spectral Vegetation Indices and Plant Canopy Modeling," is being prepared by A. J. Richardson and C. L. Wiegand. A comprehensive summary of the paper follows:

Our objectives were to develop a technique to cope with soil background reflectance variation in LANDSAT MSS digital data and to relate its information content to improved spectral vegetation indices and to the interpretation of scene component contributions to composite spectral response of soil, plant, and shadows.

The MSS digital data for five LANDSAT-1 and -2 overpass dates (4/2; 5/17; 6/4; 7/10; and 10/17/75) of the Weslaco, Texas area were studied. For each overpass, the mean MSS digital data for water, clouds, cloud shadow, high reflecting soil, low reflecting soil, and sorghum at various stages of maturity were extracted for ground-truthed land areas from LANDSAT computer compatible tapes (CCT) for bands 5 and 7. A linear regression of band 5 (dependent variable) on band 7 (independent variable) was calculated using the MSS digital means from cloud, cloud shadow, high reflecting soil, and low reflecting soil for all five LANDSAT overpass dates.

The statistics of this linear regression (Figure 2) indicated that the digital data from these diverse categories, in bands 5 and 7, were significantly correlated (coefficient of determination $r^2 = 0.972$). The regression line and standard error of estimate ($Sy.x=\pm6$) are plotted as solid and dashed lines, respectively. Since the origin is included within the dashed standard error of estimate lines, the intercept term (-1.81) is probably not significantly different from zero.

The diagram of Figure 2 indicated that the digital values for cloud, soil, and shadow for all five dates move together in bands 5 and 7 forming a family of overlapping spectral categories along the regression line. Such data obtained before planting or early in the growing season for all scene pixels would constitute a soil background mask or standard. Soil water content fluctuations and soil type would cause the point representative of a given field to move up or down along the line, but at least its path would be known. Increasing vegetation maturity or vigor would be manifested by a migration of vegetation points (signatures) away from this soil background line, so that a measure of the perpendicular distance of a vegetation point from the line probably could be used as a normalized indicator of vegetation maturity or vigor (spectral vegetation index). The intersection on the soil background line of a perpendicular drawn from a vegetative point to the line could be intepreted as the soil background signature for that particular vegetation signature. (Soil reflectance variation due to sun angle and atmospheric conditions for different LANDSAT overpass dates probably contributes to the variance about the best fit line.)

Another application of the soil background standard could be formulated in terms of plant, soil, and shadow component contributions to the observed composite reflectance.[1]

Proportion estimation theory[2] can be used to determine the fractional proportion of the plant, soil, and shadow component reflectances that will reproduce the observed composite reflectance of vegetated areas.

The soil background line could be used to determine one leg of the signature simplex triangle as illustrated in Figure 3. If, for example, high reflecting soil (Rg) were used as an upper signature simplex vertex and cloud shadow (Rs) were used as a lower signature simplex vertex, then one base leg of the signature simplex triangle would be defined in terms compatible with the regression plant canopy model. Infinite or plant canopy reflectance (Rp) could be used to define the third vertex to complete the construction of a signature simplex triangle.

Thus, the essence of proportion estimation theory can be described in terms of the regression plant canopy model as follows:

$$Rc = Rpfp + Rsfs + Rg\,(1 - fp - fs),$$

wherein

Rc is the composite reflectance of a vegetated surface,

Rp is the component reflectance due to plants,

Rs is the component reflectance due to shadow,

Rg is the component reflectance due to soil,

fp is the fractional plant cover, and

fs is the fractional shadow area.

The consistency of the plant, soil, and shadow reflectance values, as estimated by the regression plant canopy model, could be evaluated geometrically in terms of the signature simplex triangle (proportion estimation theory). Values for Rg and Rs could be selected along the bare soil background line, in a trial and error mode, until the best fit (in statistical sense) is obtained for any given set of experimental data.

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1 Richardson, A. J., C. L. Wiegand, H. W. Gausman, J. A. Cuellar and A. H. Gerbermann. 1975. Plant, soil and shadow reflectance components of row crops. Photogram. Eng. & Remote Sensing. 41:1401-1407.

2 Work, E. A., and D. S. Gilmer. 1976. Utilization of satellite data for inventorying prairie ponds and lakes. Photogram. Eng. & Remote Sensing. 42:685-694.

In conclusion, it appears that digital data from LANDSAT MSS bands 5 and 7 follow a highly predictable linear relationship for bare soils, cloud shadows, and clouds. This relationship could normalize vegetation vigor or maturity as measured spectrally and guide plant canopy models that seek to describe sunlit soil, shadowed soil, and plant reflectance contributions to observed composite reflectances of vegetated surfaces.

Estimating Leaf Area Per Plant

Leaf area per plant (LAP) is presently a time consuming and tedious parameter to determine. This parameter is needed to calculate Leaf Area Index (LAI). This report presents the results of research carried out to determine the relations between dry weight of leaves per plant (DWLP) and LAP and between length of longest leaf and LAP.

In March 1976, two grain sorghum fields (one irrigated and one non-irrigated) were selected and each was divided into 9 plots. During the period April 1 to June 9, 1976, two average-size grain sorghum plants were harvested for leaf area determinations at weekly intervals from each plot.

The leaves were removed from the stalk, and their areas were measured with an optical area meter. The areas for the leaves from each plant were totaled to obtain LAP. This was done for each sampling date.

The DWLP was determined by placing the leaves from each plant, after the leaf areas had been determined, into a paper bag and placing the bag with the leaves in a forced-air circulation oven for drying at 70°C for a minimum of 24 hr.

There was a linear relation between LAP and DWLP ($r=0.890^{**}$); LAP can be estimated from DWLP by the following linear regression equation:

$$LAP = 623.044 + 122.846 (DWLP).$$

The standard error of the regression coefficient was 7.275.

During early June 1966, 34 grain sorghum fields were selected in the non-irrigated portion of Willacy County, Texas. The length (cm) and width (cm) of each leaf were measured on each of five plants for each field. The measurements were made about 3 weeks before harvest.

The leaf area for each leaf was determined according to the following equation[3]:

Leaf area = maximum length X maximum width X 0.747.

There was a linear relation between LAP and maximum length of longest leaf ($r=0.308^{**}$). The equation for estimating LAP from maximum length of longest leaf was:

LAP = -609.861 + 26.767 (maximum length of longest leaf).

The standard error of the regression coefficient was 6.319.

In conclusion, the relation between LAP and DWLP ($r=0.890^{**}$) was stronger than the relation between LAP and length of longest leaf ($r=0.308^{**}$).

In the future, the relation of LAP to areas of individual leaves and the relation of LAP to plant heights will be studied.

C. Significant Results:

Field spectral measurements and laboratory densitometric measurements showed that tree canopy reflectance differences among the Marrs, Redblush, and Valencia varieties in the visible spectral region were due to their different leaf chlorophyll concentrations. Field measurements of visible light reflectance were directly related to the tonal responses on infrared color photos of the varietal tree canopies. Consequently, densitometric measurements of the foliage on the infrared color transparency with red-filtered light successfully discriminated among the three varieties.

Reflectance measurements with a field spectroradiometer on 9 dates (between Dec. 9 and Apr. 8) during the growing season of two wheat varieties, Milam and Penjamo, documented their spectra over the 0.45 to 2.50-μm wavelength interval associated with plant cover and physiological development. An image analyzer system was used to optically planimeter the percentage of soil background, vegetation, and shadow in the vertical photographs taken within the FOV of the spectroradiometer on each measurement date.

[3] Stickler, F. C., S. Wearden, and A. W. Pauli. 1961. Leaf Area determination in grain sorghum. Agron. J. 53:187-188.

Photointerpretation and computer classifications were produced for an 81,000-hectare rangeland area for the Oct. 17, 1975 LANDSAT-2 overpass (scene I.D. 2268-16190). Photointerpreter and computer training sites were the same. Although the extent of the land area classified into the seven range site and land use categories was similar, the computer classification is considered the more precise. For it, a decision was made for each pixel--representing 0.45 hectares of ground area--based on its spectra for bands 5, 6, and 7; whereas, the photointerpreter results were grosser and more subjective.

Progress has been made in handling soil background variations in LANDSAT data through the finding that the spectral response of various soil types, clouds, and cloud shadows are linearly related for bands 5 and 7 over virtually the whole response range of the sensors. This means the soil background can be considered a leg of a signature simplex (Work and Gilmer, Photogram. Engin. and Remote Sensing 42:685-694. 1976) with cloud shadow as one vertex and highly reflecting soil as the other. The third vertex of the triangle could be the infinite reflectance of a plant canopy. Viewed this way, the sum of squares of perpendicular distances from the soil line can be used as a vegetation density index. Additionally, the signature simplex and regression models of composite canopy reflectance composed of sunlit soil, shadows, and vegetation components become complementary.

The relation between leaf area per plant and dry weight of leaves per plant ($r=0.890^{**}$) was stronger than the relation between leaf area per plant and length of longest leaf ($r=0.398^{**}$). The relations of leaf area per plant to areas of individual leaves and to plant heights merit further study.

D. Publications:

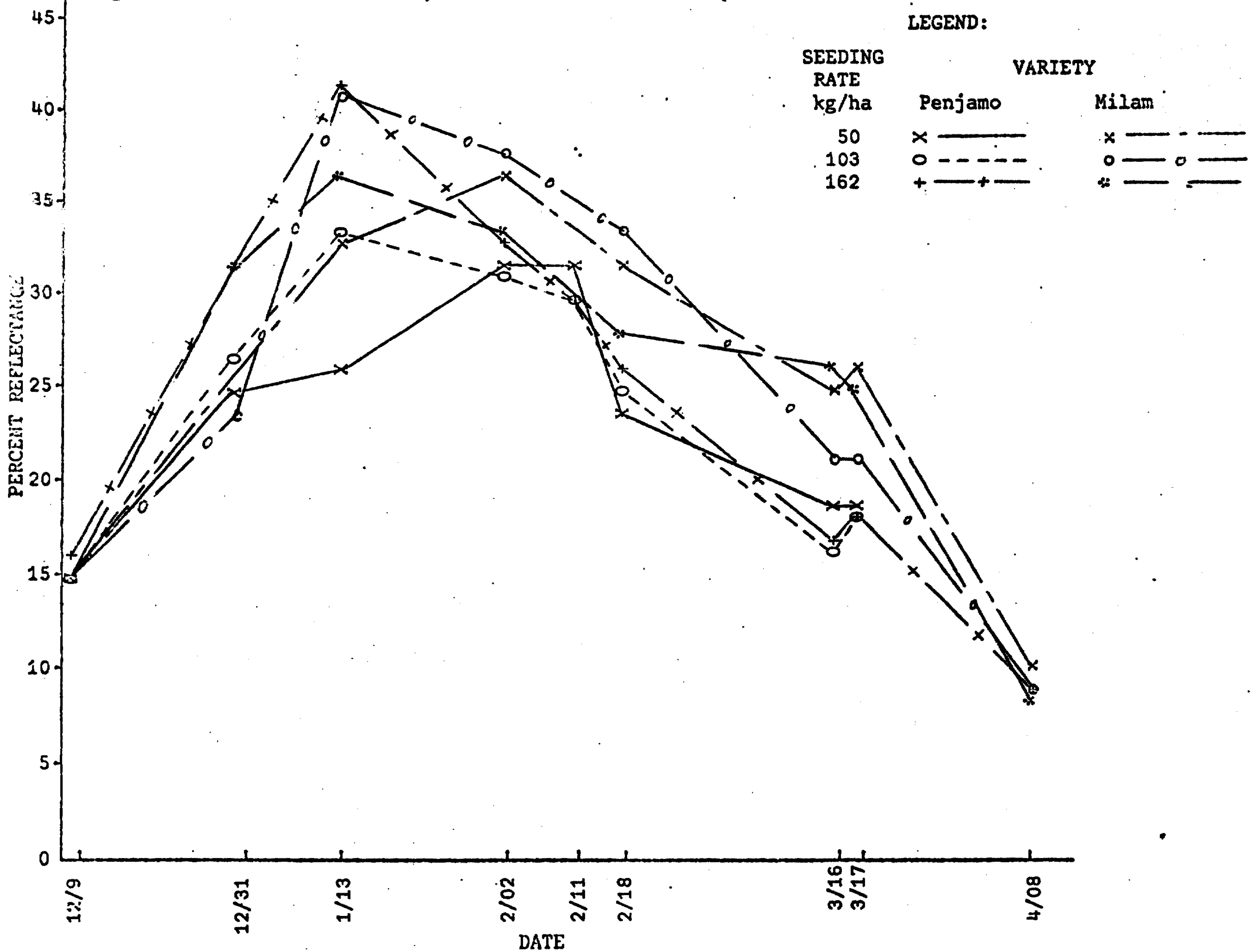
Everitt, J. H., C. L. Wiegand, A. J. Richardson, and A. H. Gerbermann. 1975. Description and LANDSAT-1 remote sensing of the rangelands of Hidalgo County, Texas. J. Rio Grande Valley Hort. Soc. 29:115-125.

Gausman, H. W., J. R. Thomas, D. E. Escobar, and A. Berumen. 1975. Cotton leaf air volume and chlorophyll concentration affect reflectance of visible light. J. Rio Grande Valley Hort. Soc. 29:109-114.

Gerbermann, A. H., C. L. Wiegand, and J. A. Cuellar. 1975. Acreage of vegetables in Hidalgo County in 1972 and 1973. J. Rio Grande Valley Hort. Soc. 29:71-79.

Richardson, A. J., A. H. Gerbermann, H. W. Gausman, and J. A. Cuellar. 1976. Detection of saline soils with SKYLAB multispectral scanner data. Photogram. Eng. & Remote Sensing. 42:679-684.

Figure 1. Reflectance at .90 μm of two varieties of wheat at three seeding rates by date.



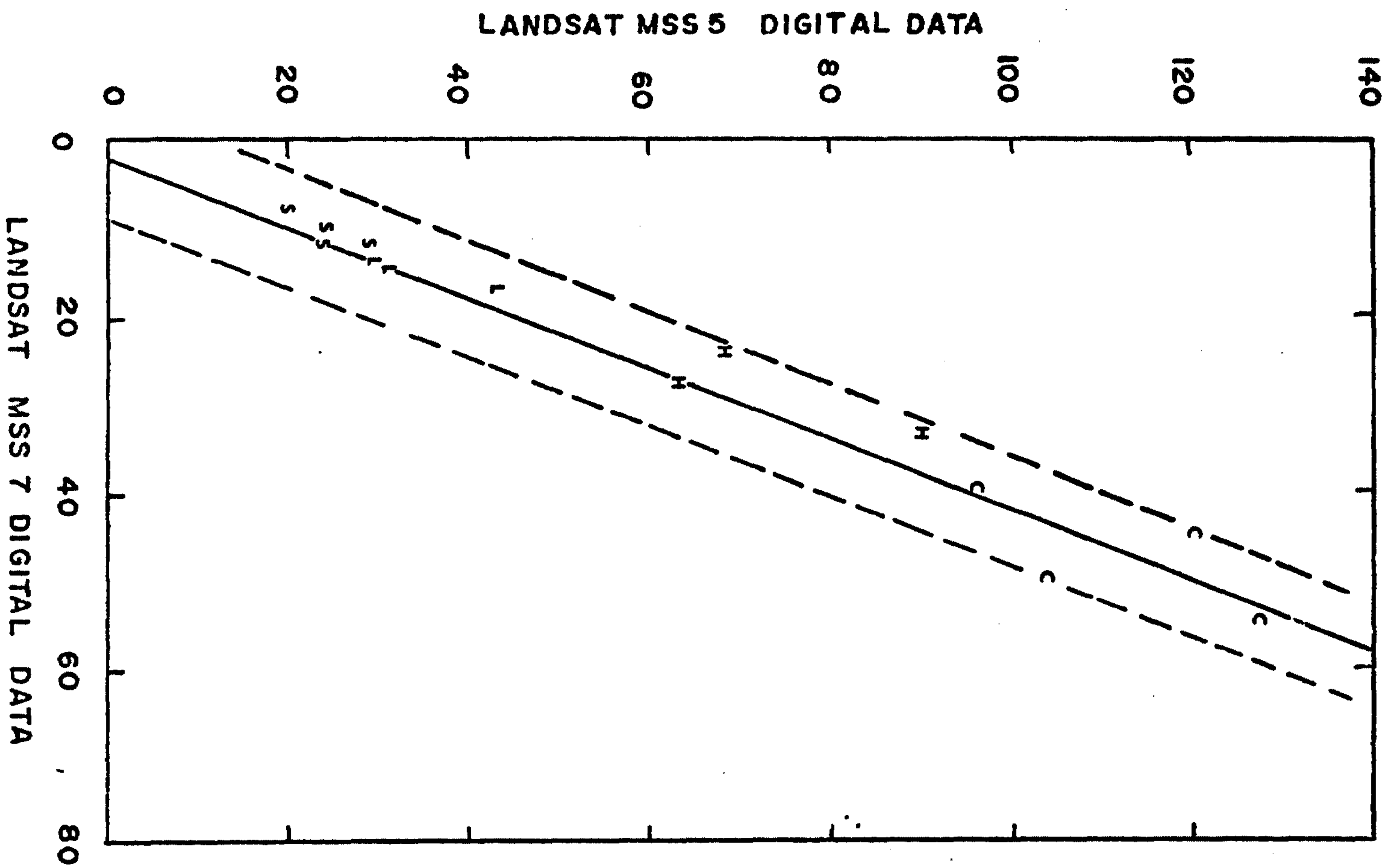


Figure 2. Bare soil background linear regression line determined using LANDSAT digital data collected on April 2, May 6, June 3, July 10, and October 17, 1975 from bands 5 and 7 for clouds (c), high reflecting soil (H), low reflecting soil (L), and cloud shadow (S). The regression line and standard error of estimate (Sy.x) are plotted as solid and dashed line, respectively. The statistics for the regression are as follows: $MSS5 = -1.81 + 2.42\ MSS7$, $r^2 = 0.972$, and $Sy.x = \pm 6$.

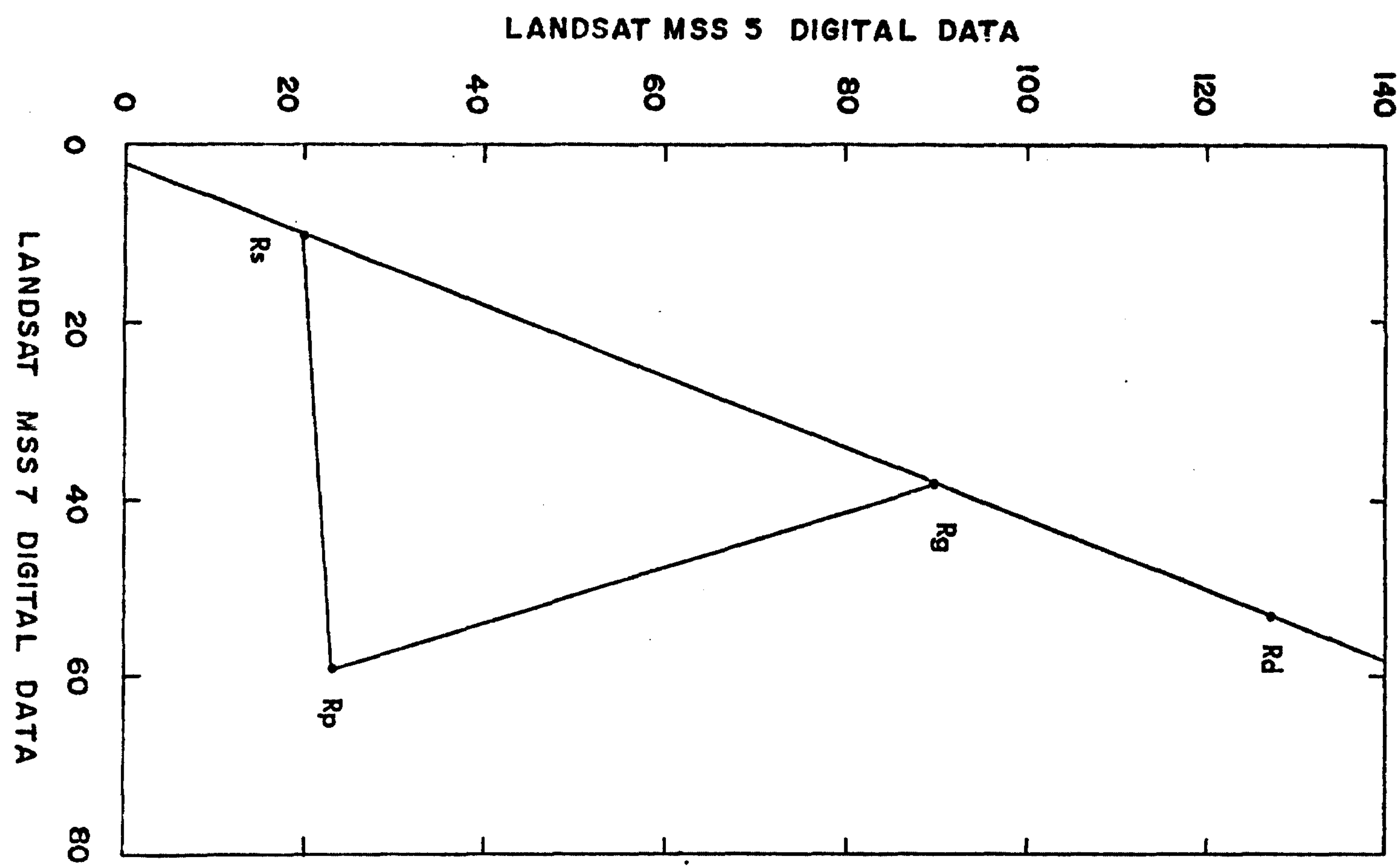


Figure 3. Signature simplex triangle constructed to geometrically represent proportion estimation theory and as a guide for interpreting plant canopy model components for plant (Rp), soil (Rg) and shadow (Rs) reflectance. The triangle leg bounded by points Rg and Rs is determined by a bare soil background line standard. The reflectance for clouds (Rc) is shown to plot on the extended bare soil background line.